SCIENCE FOR CERAMIC PRODUCTION

UDC 666.762.11:666.3.022

CERAMICS FOR MILLING BODIES

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Translated from Steklo i Keramika, No. 8, pp. 11 – 12, August, 2003.

Ceramic materials have been developed with a sintering temperature of 1475 – 1520°C, mean density of 3.55 – 3.75 g/cm^3, sealed porosity about 3%, and average strength in three-point bending 250 – 350 MPa. These materials are promising for application as milling bodies. Industrial tests indicated that the wear resistance of the specified materials in milling ceramic paints is 10 – 15 higher that that of uralite milling bodies.

Ceramics based on aluminum oxide have a set of high physicomechanical parameters: hardness, strength, and wear resistance. Such materials can be successfully used in producing structural products, including lining elements of mills and milling bodies.

Many manufacturers currently use uralite milling bodies, whose batch contains alumina, clay, and dolomite. The content of oxide aluminum in these ceramics is 74 – 75% (here and elsewhere mass content is indicated). Uralite milling bodies are produced by plastic molding. The firing temperature usually does not exceed 1420°C.

The density of sintered uralite is 2.98 – 3.00 g/cm^3, and its open porosity is below 0.1%. The bending strength of samples cut out of cylinders varies within the limits of 120 – 150 MPa. The sealed porosity is usually 1.5 – 2.0%. The size of corundum crystals is 3 – 6 μm. The amorphous isotropic phase distributed around the corundum crystals as continuous interlayers up to 10 μm thick exhibits needle-shaped mullite crystals sized from 2 to 8 μm. The quantity of mullite is around 15%, and the content of the vitreous phase in the material is about 20%. Calcium and magnesium oxides together with aluminum and silicon oxides form aluminosilicates of complex composition.

The wear of uralite milling bodies in industrial mills constitutes about 0.1 %/h, which causes contamination of the materials milled and requires frequent repairs of mills and constant replacement of worn milling bodies with new ones. Analysis of published data indicates that research in the field of development of new materials for milling bodies is mainly directed at a modification of the composition and properties of uralite [1, 2]. The main lines of this research are directed at increasing the density of the material and decreasing the amount of the vitreous phase.

The purpose of our study was to develop wear-resistant ceramics based on aluminum oxides intended to be used in milling bodies (the paper mainly describes the results of testing milling bodies with various contents of aluminum oxide developed at the D. I. Mendeleev Russian Chemical Engineering University to equip the mills at the central laboratory of the Dulevo Paint Factory).

Three types of materials were developed and tested.

Material Sh-1 is modified uralite with a decreased content of clay and dolomite containing zinc oxide and barium oxide additives. The amount of aluminum oxide is about 85%. The firing temperature of the milling body samples is 1475°C. The density of material obtained is 3.55 g/cm^3, the corundum crystal size is 3 – 5 μm, and the three-point bending strength is 250 ± 20 MPa.

Ceramics Sh-2 is modified chilumin material with an aluminum oxide content of 95%. The firing temperature is 1500°C. The phase composition is represented by corundum, mullite, clinoenstatite, and some intermediate phases. The size of corundum crystals is 3 – 5 μm, the mean density of the milling bodies is 3.73 g/cm^3, and the bending strength is 350 ± 25 MPa.

Material Sh-3 represents ceramic Sh-2 additionally modified by manganese oxide. The firing temperature is 1520°C. The milling bodies density is 3.75 g/cm^3 and the bending strength is 350 ± 22 MPa. The material has a pink color.

All samples of milling bodies were produced by hydrostatic molding. Cylinders of height and diameter 24 mm were first compressed in a metal mold under a pressure of

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TABLE 1

Testing parameters*	Material				
	Sh-1	Sh-1**	Sh-2	Sh-3	uralite
Initial mass of milling bodies, g	1405.0	1400.0	1400.0	1401.0	1400.0
Mass loss of milling bodies, g	5.0	10.0	1.5	1.0	15.0
Dispersion of material milled after 144 h of milling (minimum/maximum), μm	4/24	4/21	4/20	4/20	4/28
Abradability, %/h	0.0020	0.0050	0.0007	0.0005	0.0070

* Mass of material milled was 1000 g in all cases.

** Made by plastic molding.

50 MPa, then placed into latex and compressed in a hydrostat under pressure of 200 MPa. After drying and edge finishing, the cylinders were fired in a furnace with chromite-lanthanum heaters according to a corresponding temperature-time procedure.

A specific feature of the phase composition of all milling bodies obtained is the absence of a vitreous phase. This is provided by a preliminary calculation of the phase composition of material and, accordingly, by the batch composition.

The industrial laboratory tested the wear resistance of milling bodies of the specified compositions simultaneously with testing milling bodies of composition Sh-1 produced by plastic molding at the Élekroizolyator Works. The diameter and height of cylinders tested was 20 – 21 mm. It should be noted that milling bodies of composition Sh-3 were tested after using them for about 500 h for milling alumina. For reference purposes, milling bodies of the same size produced by the Fayans Company (Konakovo) were tested.

The material milled in testing was ceramic paint No. 685, which is a mechanical mixture of a pigment and two granulated fluxes. Milling was carried out in a porcelain drum with the ratio of material, milling bodies, and water equal to 1.0 : 1.4 : 0.5. The milling duration was 144 h. The results of the tests are shown in Table 1.

It can be seen that the hydrostatic molding method facilitates increased resistance of milling bodies to abrasion. The wear resistance of milling bodies produced by this method is significantly higher than the wear resistance of milling bodies made by plastic molding.

The abrasion resistance of milling bodies of composition Sh-3 is 15 times higher than that of uralite cylinders produced by the Fayans Company.

It should be noted that the paints milled by the milling bodies developed at the D. I. Mendeleev Chemical Engineering University significantly surpass the paints milled by uralite cylinders in all parameters.

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